Medieval weather prediction

Article

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Medieval Meteorology

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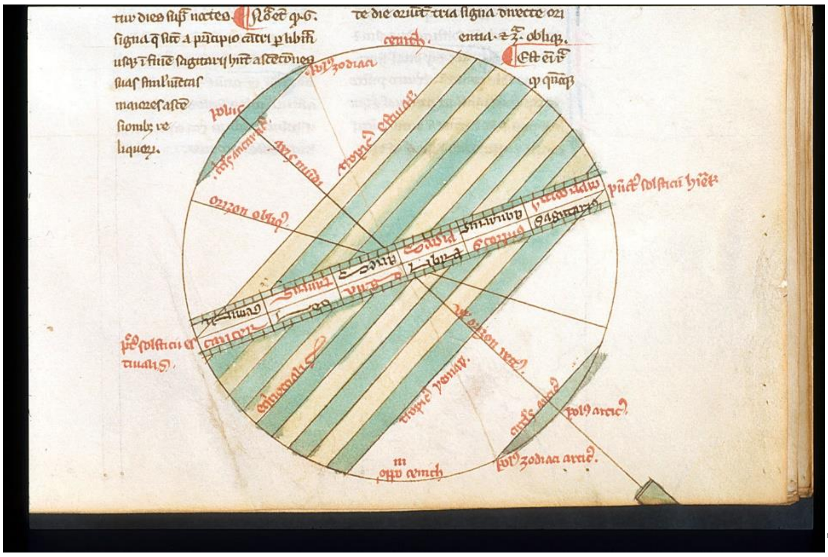
Headline: Classical meteorology did not die in the middle ages but was radically improved to become an international science of weather-forecasting

©P. Lawrence. Salisbury, England. Observation of clouds, sunbeams and birds was an important element of classical weather forecasting; but medieval astrometeorology drew upon planetary data and weather records to produce longer-term forecasts.

Meteorologists, not least through their role in producing weather forecasts, are now well-established as providing essential contributions to society. It is also widely known that the first daily forecasts appeared in *The Times* (of London) in August 1861. The term itself was created by Robert FitzRoy, who wished to distance his work from astrological 'prognostications'. All this has led to a widespread assumption that weather forecasting is an entirely modern phenomenon and that in earlier periods only quackery or folklore-based weather signs were available. More recent research has demonstrated that astronomers and astrologers in the medieval Islamic world drew widely on Greek, Roman, Persian and Indian knowledge in order to create a new science of 'astrometeorology'. This was enthusiastically received in Christian, Latin Europe, and was used and developed by astronomers such as Brahe and Kepler. The drive to produce reliable weather forecasts led to the belief that astrometeorological forecasting could be made more accurate if precise observations and records of weather were used to refine forecasts for specific localities. Such records were kept across Europe from the fourteenth century on, and correlated with astronomical data, in a way which paved the way for the data-driven forecasts produced by FitzRoy.[i]

Islamicate astrometeorologists replaced the ancient practice of observing short-term weather signs, such as clouds or the flight of birds, with a new science. This was based on the belief that weather is caused by the atmospheric effects of the movements of the planets, mediated by regional and seasonal climatic conditions. Improved modelling of planetary orbits, coupled with updated geographical and meteorological information, made this new science both possible and compelling.[ii]



This illustration from Sacrobosco's thirteenth-century textbook on astronomy, *De sphera,* shows the 'equinoctial circle' (equator, labelled in red) the Tropics (labelled 'winter' and 'summer') and the Arctic and Antarctic circles, all surrounded by the zodiac. These climatic zones and celestial divisions were fundamental to astrometeorology. ©British Library Board, Ms. Harley 3647, f29r.

The prospect of acquiring reliable weather forecasts, closely linked to predictions of coming trends in human health and agricultural production, made the new meteorology as attractive in Christian Europe as it was in the Islamicate world. Considerable pride shines through medieval, Christian accounts of the new questions about weather which could now be answered. Central amongst these new questions was one which classical meteorology had failed to answer fully. It was: how, when the seasons are caused by regular, repeating patterns, produced by the Earth's spherical shape and its interactions with the Sun, can seasonal weather vary so much from one year to the next? This very question was put into the mouth of Geoffrey of Anjou, father of King Henry II of England, by the twelfth-century philosopher, William of Conches.[iii] Happily, William was able to provide a 'modern' answer. Drawing on translations of works attributed to Māshā'allāh (c762-815), as well as recent discussions by Adelard of Bath and Constantine the African, William expounded

Ptolemaic models of planetary movements and Islamicate theories of their impacts on local seasons and weather.

The body of scientific material being translated from Arabic continued to grow well into the thirteenth century. Texts on astrometeorology were very popular, for reasons which are not hard to understand. Philosophers like William argued that rulers had a duty to understand the world; but rulers also had more practical concerns with matters such as military strategy and food supply, which were heavily affected by weather. It is also significant that the twelfth and thirteenth centuries saw a long period of rising population, with wealth, urbanisation and long-distance trade all growing. Bankers and traders were also willing to pay for such valuable information. Nor was astrometeorology a short-lived phenomenon. It was greatly developed in during the fourteenth and fifteenth centuries, reached ever-growing audiences in the sixteenth and seventeenth, and only fell from favour in the eighteenth.

How astrometeorology worked

Central to astrometeorology was the universal belief that the planets, and their movements around the Earth, affected atmospheric conditions and weather. Therefore to make an astrometeorological forecast it was first necessary to be able to calculate the positions of the planets and stars, in relation to the chosen geographical location, for the relevant date(s). The planets' positions in relation to one another, and their directions of movement, were also major factors. Hellenistic scientists, with Ptolemy of Alexandria at the forefront, had made major advances in this field, and Ptolemy had produced geometrical and mathematical models of planetary movements, based on recorded observations built up over centuries as well as on new observations which he carried out himself. Ptolemy's fundamental works, generally known in the medieval period as the *Almagest* and the *Tetrabiblos*, provided: the means for calculating planetary positions; and guidelines for interpreting this data.

The theory was that each planet had a specific set of qualities and powers, which exercised influence over related phenomena on Earth. Saturn, distant, slow-moving and cold in colour, was associated with the cold, dry element of earth; while Mercury, small, fast-moving and usually close to both Venus and the Moon, was associated with the warm, moist element of air. Exactly how planetary influences were exercised was a matter of some dispute, but the most widely-accepted argument was that they emitted rays, imperceptible to human senses, which could reach the Earth. The rays carried the powers of the emitting planet; for instance, Saturn's influence was classified as markedly dry and cold. Most significant were the Sun and the Moon. The power of the former over light, heat, climate and season was long-established. The Moon's influence over ocean tides, bodily fluids and plant growth was also well known, at least to the educated. These 'greater luminaries' were so powerful that they could modulate the influences of weaker planets. In the case of the Moon, its exact effects were further affected by its phase. As Ptolemy put it: 'It is clear that when the planets are in significant associations with one another they produce very many variations in the quality of our atmosphere, with the intrinsic power of each remaining but being modified in its strength by the forces of the bodies with which it is configured'.[iv]

The first step in making a forecast was to calculate the positions of all the significant celestial bodies, on the chosen date, in relation to the ecliptic (the apparent path of the Sun around the heavens) and to the belt of the zodiac. Both were envisaged as circular, and the zodiac was divided into twelve equal sectors (the 'houses' or 'signs'). These portions of the heavens had characteristics of their own, which acted upon any planet passing through them. Ptolemy both systematised and explained this. It was also important to note the angular relationships between planets, since these determined their mutual effects. Planets facing one another across the zodiac were in a negative relationship to one another. Also problematic, and likely to produce atmospheric disturbance, was an angle of 45°. However, planets at 60° or 120° would interact much more positively. When planets were close together the power of both would usually be increased, with effects depending upon the natures and placements of the planets involved. Of course, the forecaster also needed to take account of the climatic zone within which the chosen place was situated, and the season of the year. An increase in atmospheric heat would have one set of effects in summer near the Equator and another in winter near the Tropic of Cancer. An apparently simple set of principles in fact required the forecaster to make judgements as to the outcomes of all the factors at play.

This fourteenth-century English astrolabe (Image © Museum of the History of Science, Oxford) illustrates the assimilation of Islamicate astronomical instruments. It provides a map of the heavens, calibrated for a chosen latitude, with pointers to named stars.

The calculations were dependent upon the achievements of Islamicate astronomers, who had built accurate and updated models and tables of celestial structures and motions. These in turn drew upon advances in mathematics and the making of scientific tools and instruments. The astronomers also tested and revised Ptolemy's instructions for making weather forecasts, with many producing their own treatises on the subject. These specialist works not only provided guidance through the basic techniques but also drew on the updated planetary data as well as on new cosmological models.[v] The result was a sophisticated, enticing, but challenging body of material which posed problems for those new to the field.

The Rise of the Expert Forecaster

The extent of the scientific advances being made in the Islamicate world was recognised in Latin Europe from the eleventh century on, and stimulated curiosity and emulation rather than rejection. Territorial conquests by Northern forces in al-Andalus made libraries, scholars and translators available to the new, Christian rulers. Thus was born one of the greatest movements for scholarly translation and cultural assimilation in European history. Works on astrometeorology had an honourable place within this. The attraction of this knowledge is demonstrated by the enthusiasm with which translations of updated versions of Ptolemy's Tables of planetary movements were received, despite requiring users to grapple with a foreign calendar and dating system and with Hindu-Arabic numerals and the unfamiliar mathematical concepts which they entailed. Several Islamicate philosopher-scientists became established as authorities in Christian Europe, even if under Latinised versions of their names.

One such was Abu Mā'Shār (c787-c886 CE) known in Latin as Albumasar, who spent most of his career in Baghdad, where he wrote a series of important works. Another was Māshā'allāh (Messehalla) who also worked in Baghdad in the golden age of the science of the stars. The latter wrote an influential survey of astronomy and astrology, which devoted six of its twelve chapters to astrometeorology. Perhaps most celebrated for his meteorological expertise, at least in the Latin world, was al-Kindi (c801-873 CE). Treatises on weather forecasting, extracted from his longer works and circulated in Latin translation, remained popular into the Renaissance. They offered a clear explanation of how the atmosphere and the weather worked, together with the specific causes of heat and cold, drought and rain. The conceptual framework was Aristotelian, as was the central idea that the fundamental driving force is heat, itself the result of the energy generated by planetary movements. Linked to this was the concept of the four elements composing the sublunar zone (earth, air, fire and water) and their intrinsic connections to the primary qualities of hot, cold, dry and moist.[vi] The fixed stars, including those making up the constellations to which the houses of the zodiac were linked, as well as the planets, were held to have special affinities with individual elements as well as with qualities. These underlay and determined the nature of the effects each planet would have on the terrestrial world as it moved through the heavens. An outline of the resulting system of affiliations and effects is given, for instance, in chapters Four and Five of the *Speculum Astronomiae (Mirror of Astronomy)* attributed to the influential thirteenth-century theologian, Albert the Great.[vii]

In al-Kindi's method of forecasting the first step, as usual, was the calculation of the relevant planetary positions and directions. Interpretation started with the position and strength of the Sun, the most powerful producer of heat and energy. Special attention is next given to the Moon, including to its phase. In al-Kindi's model the Moon had particular power over the element of earth, as well as of water, and this would be modulated on any given day by its position in relation to the Sun.[viii] Assessment of this interaction was important for forecasting winds, since the joint influence of the Sun and Moon determined whether the air in a particular region would be hot or cold. Heated air would expand rapidly into zones where cooler air had contracted, and this in turn would determine the strength and direction of winds. Consideration of the other five planets followed, entailing calculation first of the factors affecting each planet individually. This then would be modulated by consideration of the groupings of planets and their interactions. Such techniques required considerable confidence in judging which factors would have the greatest effects and for how long, and it was accepted that experience played a major part success. Experts put their trusted methods on record, for the benefit of others. If the forecasts of novices were less successful, that would clearly be due to their lack of expertise. In al-Kindi's case, his application of the concept known as 'the opening of the doors' was very influential. This identified specific combinations of planets, and their movements in relation to one another, as especially likely to cause rain. The treatises do not explain the phrase, but it suggests an almost physical change in the atmosphere, such that water was released.

Timing and extent of rainfall is always important, but its prediction was sufficiently valued in Islamicate science that treatises on weather forecasting were frequently known as 'books of rain'. Another important addition to the basic, Ptolemaic model were the 'mansions of the Moon' (also known as 'stations' or stopping places). These were credited to Indian astrologers and were based on twenty-eight fixed stars or star-groupings, each of which occupied a sector of the Moon's path through the zodiac. Each mansion was characterised in terms of its degree of humidity or aridity, which would in turn affect the Moon. Four key times each month were specified, when the character of the mansion occupied by the Moon would especially affect the weather. The general pattern of weather for a month could be forecast by drawing up charts for each of these times. If the Moon is in (or moving into) a wet mansion at one such point then the outcome would normally be rain. However, a significant interaction of the Moon with Saturn would considerably modify this, and the disruptive influence of Mars would make storms, thunder and hail likely. These factors would diminish in power as the Moon moved on, and would be supplanted when the next key point was reached.

The spread of astrometeorology

Interest in Latin treatises on astrometeorology continued to grow, from the thirteenth century onward, and was not affected by religious concerns. Forecasting of weather was viewed quite differently from the making of personal, astrological predictions for individual clients. The latter was at best fraudulent, and at worst heretical and dangerous, due to its clash with important teachings on free will. These considerations did not apply to the weather. An important endorsement came from the great thirteenth-century theologian, Thomas Aquinas. Aquinas dealt with the power of the stars over earthly things in his *Summa Theologiae,* and cited St Augustine's statement that the heavenly bodies can indeed cause physical effects in things below. When discussing divination Aquinas was equally clear that weather forecasting on the basis of the stars is an application of knowledge drawn from observation and experience, and thus has nothing demonic or divinatory about it.[ix] For students, especially in Paris, the authoritative, contemporary survey of all forms of astrology, the *Mirror of Astronomy* (mentioned above) was important. This work concluded that true knowledge of the ways in which changes in the heavenly bodies bring about changes in earthly things, including the weather, is a very valuable outcome of the study of the stars, whose value is great even though it has come from other societies and languages.[x] Technological developments also played a part in the dissemination of the new science, especially in the form of the printing press, which arrived in northern Europe in the fifteenth century. This made it possible for long term weather forecasts, combined with calendars and predictions of trends in health and politics, to be issued in the useful form of the annual almanac.

The almanacs grew out of the predictions and forecasts commissioned by the rich and powerful from renowned scientists and holders of university chairs in astronomy. This demand had appeared almost as soon as the new meteorology reached Latin Europe. An early example was that of the astrologer, Guido Bonatti, who advised Guido da Montefeltro (1223-1298) ruler of Urbino, amongst others. Bonatti recorded his trusted techniques in a book which circulated widely in manuscript and went into print very early (in Augsburg, in 1491). This work was divided into six parts, of which one was devoted to astrometeorology. An updated and beautifully illustrated copy was made for King Henry VII of England in 1490 and is now in the British Library.

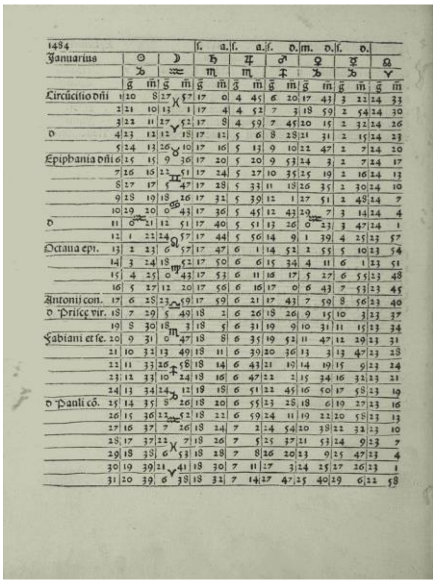
©British Library Board, Ms Arundel 66, f. 201; Henry VII being presented with his astrological compendium.

The thirteenth and fourteenth centuries saw impressive investment in universities across Europe, and both astronomy and astrology were important in this. Meteorology was an integral part of both subject areas. The most famous fourteenth-century centre was Paris, with rivals appearing at Oxford, Vienna, Bologna, Padua, Louvain, Magdeburg, and Krakow, amongst many others. The demand for the expertise of astronomer/astrologers is illustrated by the career of Georg Peurbach, who studied in Italy, France and Germany. He worked for Ladislaus V of Hungary and Bohemia (1440-57) and the Emperor Frederick III (ruled 1452-93) and also became a professor of astronomy at the university of Vienna. Forecasts and predictions made for powerful rulers would be private; but holders of university chairs were often required to provide public guidance. This was given to both members of the university and patrons, in the form of 'annual prognostications'. The earliest of these to survive date from the early fifteenth century, and they were obviously a matter of civic pride since the custom quickly spread.

The prognostications of Master Peter of Monte Alciano, of Pavia, seem to have been especially sought after. His forecasts for 1419, 1421, 1430 and 1448 all survive and reached not only the Empire but also France and England. But perhaps most influential was Joannes Vesalius (great-grandfather of the author of the *De humani corporis fabrica*) who took a position at the university of Louvain in 1429 before becoming an adviser to Duke Philip the Good of Burgundy. The city council of Louvain commissioned a prognostication for 1431, which Vesalius duly read to an invited audience at the end of 1430. Further such predictions were commissioned for Louvain at least in 1439 and 1440, and were followed by forecasts for the duke. When Louvain's first printer, Jan van Westfalen, arrived he promptly issued annual prognostications, modelled on those of Vesalius. Similarly, prognostications were made for Matthias Corvinus, King of Hungary (1458-90) by Martin Bylica. Strikingly, the university of Bologna was employing two professors of astronomy and astrology. One was required to draw up an annual almanac, showing the positions of all seven planets on a daily basis for the coming year, and tabulating the aspects of the planets to the Moon and to one another. The other was to use this data to produce a prognostication.[xi] This is exactly the formula followed by the printed almanacs.

Much of the hard work of calculating the planetary positions was alleviated by the contribution of the astronomer, Regiomontanus (1436-76). He produced a *Calendar* and *Ephemerides* which were made available in print from 1476. These large volumes not only provided full planetary data but also guidelines for its interpretation, and a table of adjustments to be applied in order to adjust the coordinates for any major city or region in Europe. The powers of each planet in each sign and each aspect are tabulated in numerical form, and the lunar mansions are also set out in a table. Regiomontanus also provided his Rules for producing prognostications, and the very first section of these deals with weather forecasting. These apply the standard procedures, while conveying the impression that they represent Regiomontanus' own practice. The season of the year is to be considered first, followed by the effects of the signs on each planet. Next comes the analysis of aspects, with special emphasis placed on the effects of groupings of planets in signs associated with the same element. For instance, if several planets are in aspect with one another in the summer, and all in Fire signs, excessive heat and drought will be caused. In winter this will merely lessen the seasonal cold and wet. Details are assessed by considering the power of each individual planet. An unusual factor is the consideration of the nature and power of any fixed star close to any of the planets involved. Special attention is given not only to the Moon but also to Saturn. Moreover, specific occurrences are identified as especially influential. For instance, an opposition of the Moon and Jupiter, involving the Fire sign of Aries and the Water sign of Scorpio, will generate clouds; if the Moon is moving towards

Mercury there will also be an 'opening of the doors' of the winds. For traditionalists, Regiomontanus' Rules were followed by a separate section offering 'Weather forecasting according to al-Kindi'.



©Universität Wien. Regiomontanus' calendar page for January 1484 shows the zodiac positions of the seven planets throughout the month, simplifying prognostication.

Astrometeorology and the Scientific Revolution

High demand for Regiomontanus' works meant that multiple printed versions rapidly appeared, many of them pirated. He was acclaimed as the greatest astrologer of his times, and consequently employed by both Cardinal Bessarion and King Matthias Corvinus of Hungary, while his work was used by Columbus to calculate the dates of coming storms.[xii] His espousal of astrometeorology was echoed by other great names of early-modern science, including Tycho Brahe and Johannes Kepler. The growing acceptance of a heliocentric universe did nothing to challenge the belief that the celestial bodies affected the atmosphere and the weather of Earth, as well as the health of the human body. Indeed, ongoing refinement of the rules for making weather forecasts reinforced astrometeorology's place in both scientific and popular culture, rather than challenging it.

This trend appeared in several centres from the middle of the fourteenth century. Particular interest was shown by the astronomers and scientists working at Merton College, Oxford, from c1340, with John of Ashenden prominent. John composed an enormous *Summa* on astrology, with astrometeorology dominating its long second section. He achieved fame for having predicted the Black Death of 1348/9, and his weather forecasts for 1368-74 placed emphasis on the major planetary conjunctions of 1365 and 1369. These suggested a period of heavy rain and floods to be followed by three years of drought. Crop failures and food shortages were thus to be expected. Parallel with Ashenden's work were the more local studies of weather and its prediction recorded in treatises presented to Merton by a Fellow of the college, William Reed (bishop of Chichester, 1369-85). Amongst these was a set of 'Rules for the forecasting of weather, by Master William de Merle', which were accompanied by detailed weather observations for 1337-44, mostly made in Lincolnshire but including some from Oxford. The central aim here seems to be to correlate astrometeorological factors with notes of actual weather, in order to establish which factors proved most significant for making predictions.[xiii] These researches were perhaps inspired by the pioneering work of the Franciscan, Roger Bacon, undertaken in Oxford in the late thirteenth century. Amongst a collection of his scientific treatises is a calendar, with daily planetary positions and accompanying notes on the weather.

A similar project, separate from that in Oxford, was undertaken by Eyno of Wurzburg, whose treatise on astrometeorology was backed up by the inclusion of notes on actual weather for 1331-55. Like the Oxford group, special emphasis is placed on achieving advance warning of damaging weather; Eyno records with some pride that he successfully forecast heavy snow on three separate occasions. Finally, a volume belonging to the Dominicans of Basel, but of uncertain origin, records comparable work in the period 1399-1406. Here too selected rules for astrometeorological prediction are accompanied by several sets of records and observations of weather. Notes identify which astrometeological factors would match the recorded weather. For instance, April 7, 1400 was cloudy, with short sunny intervals and a strong West wind. A note points out that the Moon moved away from the beneficent planet, Jupiter, and also out of an Air sign, and towards Mercury (known to cause disturbance of the air).[xiv]

The argument that such research was intended to improve and sharpen astrometeorology rather than to challenge it is supported by the expansion of the science throughout the fifteenth and sixteenth centuries. The arrival of annual forecasts, made public both by readings and in print, has been outlined above. In the sixteenth century came the production of treatises making it possible for amateur scientists to carry out their own forecasts, as well as the publication of ever-increasing numbers of annual almanacs and prognostications. These were published in the local language, rather than the Latin of the more theoretical works. Those in English are striking for the long-lived vocabulary they deployed. For instance, Buckminster's *Almanacke and Prognostication* for 1598 opened with an overview of the weather for the year (which can only be described as depressing) before moving on to one-line forecasts for individual days in each month. Spring began when the Sun entered Aries (March 10) and the start of April would see 'fair' and 'fresh' weather. The Moon's first quarter (3 April) saw a change to cloudy, cold weather, becoming 'raw' on 6 April. Full Moon (11 April) would see the weather becoming 'clear' and 'fair'.

Further evidence for the ongoing value placed on astrometeorology is provided by the work of the well-known astronomers, Tycho Brahe (1546-1601) and Johannes Kepler (1571-1630). The former devoted surprising space to astrometeorology in his 1572 treatise on the new star which appeared in Cassiopeia. He gave his own observations and calculations on meteorology and supported the publication of daily weather forecasts. The problem of inaccuracy was acknowledged, but Brahe still argued that keeping of weather records would strengthen astrometeorological practice.[xv] Brahe's pupil, Kepler, followed this advice and made daily records of weather. His published *Ephemerides* and *Calendars* included both his weather observations and his forecasts. Like other practitioners before him, he identified the factors which he believed to be most important – in his case, planetary aspects. Such distinguished support for 'medieval' meteorology makes it impossible to hold to the view that it was the result of superstition and ignorance. As has been shown, the production of updated and corrected observations of planetary movements had made it possible to draw up the planetary tables used by astrometeorologists. Similarly, the belief that accurate recording of the weather would strengthen forecasting techniques was a major legacy of astrometeorology to its modern successor.

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[i] See A. Lawrence-Mathers, *Medieval Meteorology; Forecasting the Weather from Aristotle to the Almanac,* Cambridge, University Press, 2019.

[ii] This article draws on research undertaken during the AHRC funded project, Medieval Meteorology. I am very grateful to the AHRC for their support.

[iii] For William's text see *William of Conches; A Dialogue on Natural Philosophy (Dragmaticon Philosophiae),* Trans. I Ronca and M. Curr, Notre Dame, Indiana, University of Notre Dame Press, 1997. For discussion of William's sources see B. Obrist, 'William of Conches, Masha'Allah and Twelfth-Century Cosmology', *Archives d'Histoire Doctrinale et Littéraire du Moyen Age,* 76, 2009, pp.29-87.

[iv] Ptolemy, *Tetrabiblos,* Ed. And Trans. F.E. Robbins, Cambridge, Harvard University Press, 1940; Book 1, chapter 8.

[v] See J. al-Khalili, *The House of Wisdom: How Arabic Science Saved Ancient Knowledge and Gave Us the Renaissance,* New York, Penguin, 2011.

[vi] An outline of this theory and its importance in medieval science is provided by E. Grant, 'Cosmology', in D.C. Lindberg and M.H. Shank, *Cambridge History of Science,* Volume 2, *Medieval Science,* Cambridge, University Press, 2013, pp. 436-455, esp. pp. 440-441.

[vii] See P. Zambelli, *The Speculum Astronomiae and Its Enigma,* Dordrecht/Boston/London, Kluwer, 1992, Text and translation, chapters 4 and 5, pp. 221-226.

[viii] Al-Kindi, Ed. G. Bos and C. Burnett, *Scientific Weather Forecasting in the Middle Ages: the Writings of al-Kindi,* London and New York, Kegan Paul International, 2000.

[ix] Thomas Aquinas, *Summa Theologiae:* Part 1, Question 115, Article 3; and Part 2 (Second Part), Question 95, Article 5. A useful translation is provided on the New Advent website: newadvent.org/summa/ (accessed 16/10/2020).

[x] For text and commentary see *The Speculum Astronomiae*, pp.214-219; 230-231; 250-253.

[xi] On this see S. Vanden Broecke, *The Limits of Influence; Pico, Louvain and the Crisis of Renaissance Astrology,* Leiden, Brill, 2003.

[xii] For his work in Hungary see for instance D. Hayton, 'Martin Bylica at the Court of Matthias Corvinus: Astrology and Politics in Renaissance Hungary', *Centaurus*, 49, 2007, pp.185-98. Columbus made use of Regiomontanus' almanacs to calculate times when storms were likely; see E. Zinner, Trans. E. Brown, *Regiomontanus: His Life and Work,* Studies in the History and Philosophy of Mathematics, 1, Elsevier/North Holland, Amsterdam/New York/Oxford/Tokyo, 1990, pp. 120-24.

[xiii] See W. Merle, Ed. G.J. Symons, *Merle's MS. … The earliest known journal of the weather … 1337-1344,* London, 1891 (privately printed).

[xiv] L.Thorndike, 'A Weather Record for 1399-1406 AD', *Isis,* 32, 1940, pp.304-23; and 'A Daily Weather Record from the Years 1399 to 1401', *Isis,* 57, 1966, 90-99.

[xv] Tycho Brahe, *De nova stella, 1573,* Ed. Regia Societas Scientiarum Danica, 1901.